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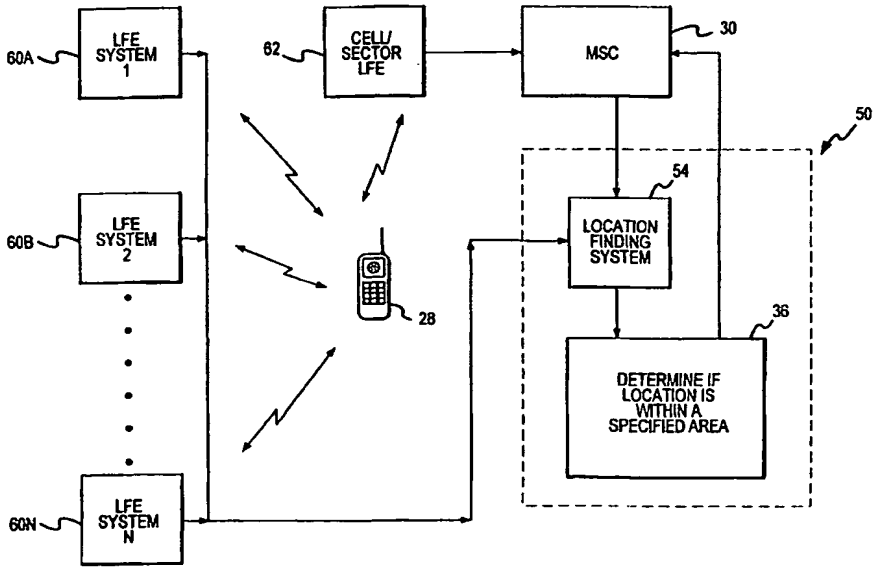

(57) Abstract

A method for determining (36) whether a location associated with a wireless station, such as a cellular telephone (28), is located within an area of interest. The area of interest is defined using a quadtree representation of an area that includes the area of interest and identifying nodes within the quadtree that represent the area of interest. By iterative comparison of the location (60A–60N) associated with the wireless station (28) to the locations associated with a node at each level of the quadtree, a determination can be made as to whether or not the location associated with the wireless station is within the area of interest.

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METHOD FOR DETERMINING IF THE LOCATION OF A WIRELESS COMMUNICATION DEVICE IS WITHIN A SPECIFIED AREA

FIELD OF THE INVENTION

The present invention is related to wireless telecommunication systems and, in particular, to the determination of whether the location of a wireless telecommunication device is within a specified area.

BACKGROUND OF THE INVENTION

Wireless telecommunication systems facilitate radio communications between a wireless station, e.g., a cellular telephone (analog, digital and PCS), and other communication devices. Typical of wireless telecommunication systems is a cellular telephone system that facilitates calls to and from cellular telephones within a predetermined service area. The service area of a cellular telephone system is normally subdivided into areas known as "cells." Associated with each cell is a base station antenna that facilitates radio communications with cellular telephones within the cell. The base station antennas of all the cells in a service area are in communication with a mobile switching center ("MSC") that establishes a communication channel between the cellular telephone located in the service area and another telecommunication device. In operation, the MSC establishes a communication channel between a cellular telephone located in the service area and another telecommunication device (e.g., another person's cellular telephone or a land-line telephone). Once the channel is established, communications are relayed between the cellular telephone, the base station, the MSC and the other telecommunication device.

An important characteristic of many wireless stations is mobility. In the case of cellular telephones, a subscriber to a cellular telephone system can conduct calls in the service area and, in many cases, in areas outside of the subscriber's service area. This mobility has lead to the development or proposed development of tools for determining the location of a wireless station. For instance, when a cellular telephone is used to place a "911" emergency call, determining the location of the cellular telephone would be highly desirable so that emergency personnel can assess how best to reach the individual in distress. This is especially important in situations involving remote locations where precise locational information cannot be given or the individual cannot provide locational information due to an injury.

A number of devices have been developed for providing locational information of wireless stations. For example, in cellular telephone systems, the communication protocol used within the system identifies the cell in which a cellular telephone is located when the call connection is established. In many applications, this may provide sufficient locational information. However, because the area covered by a cell can be large, especially in rural settings, more accurate devices have also been developed. For instance, various devices have been developed that use information provided by two or more antennas to provide locational information by triangulation.

SUMMARY OF THE INVENTION

The present invention is directed to determining whether the location associated with a wireless station is within a predetermined area of interest. Such a determination is of considerable value in many situations. For example, such information would be valuable in "911" emergency service situations in mountainous areas where it is commonplace to have one rescue squad be responsible for rescues on one side of a mountain range and another rescue squad be responsible for rescues on the other side of the range. By being able to determine the area (side of the mountain range) within which a call for help is being placed via the "911" service, the present invention facilitates the dispatch of the rescue squad best positioned to respond to the emergency.

To determine whether the location associated with a wireless station is within a predetermined area of interest, the invention uses a "quadtree" computer data structure that represents the area of interest. The quadtree representation of the area of interest facilitates iteratively and quickly determining the area in which the location associated with the wireless station is situated. Once this area (known as a quadrant) has been determined, the quadtree structure further provides an indication of whether or not the quadrant is part of the area of interest. The quadtree data structure can also be updated to reflect changes in the area of interest or to add new areas of interest with little impact upon the telecommunication system in which the invention is implemented.

The quadtree is a multi-level structure with each level representing the same surface area of the earth but higher levels representing the surface area with a higher degree of resolution. In one embodiment, the first level of the quadtree represents the entire surface of the earth and is conceptualized as a "square". The second level of the

quadtree represents the four quadrants of the earth's surface, where the first quadrant extends from 0° to 180° longitude and from 0° to 90° latitude; the second quadrant extends from 0° to 180° longitude and from 0° to -90° latitude; the third quadrant extends from 0° to -180° longitude and from 0° to 90° latitude, and the four quadrant extends from 0° to 180° longitude and from 0° to -90° latitude. The second level of the quadtree can be conceptualized as four smaller "squares". These four smaller squares are the four quadrants of the "square" associated with the first level. It should be noted that the portions of the earth's surface that are represented by these four smaller squares are not actually squares due to the curvature of the earths surface. As such, the term "square" is used to aid in visualizing the quadtree. The third level of the quadtree represents sixteen "squares", four groups of four "squares". Each group of four "squares" represents all of the quadrants of one of the squares represented by the second level of the quadtree. So, for example, if one of the "squares" associated with the second level of the quadtree represented the portion of the earth's surface that includes North America, each of the group of four "squares" at the third level that comprise the "square" at the second level would represent one of the quadrants of North America.

It should be appreciated that the area of the earth's surface represented by a "square" at a level decreases as the level increases. For example, the area of the earth's surface represented by a "square" at the third level of the quadtree is considerably less than the area of the earth's surface represented by one of the "squares" at the second level of the quadtree. A quadtree representation of the earth's surface that includes 32 levels provides accuracy to within one centimeter.

The quadtree structure is adapted to identify one or more areas of interest by associating with each square at the highest level, i.e., the smallest squares, a flag or other indication that the square is part of the area of interest. For example, if the quadtree representation of earth's surface has been extended to 10 levels and the area of interest is Los Angeles, a certain number of the squares at level 10 will be identified or "flagged" as representing Los Angeles.

In one embodiment, the portions of the quadtree structure that have been "flagged" (i.e., belong to the area of interest) are reviewed to determine if the quadtree structure can be condensed. This review involves assessing whether each "square" of a group of four "squares" that represent a larger "square" of a preceding level of the